(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 866 488 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.09.1998 Bulletin 1998/39

(21) Application number: 98104436.5

(22) Date of filing: 12.03.1998

(51) Int. Cl.[6]: **H01J 9/32**, H01J 61/36, H01J 61/30, H01J 61/82, H01J 61/84

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 17.03.1997 JP 62661/97

(71) Applicant:
Matsushita Electric Industrial Co., Ltd.
Kadoma-shi, Osaka 571-8501 (JP)

(72) Inventors:
- Horiuchi, Makoto
Sakurai-shi, Nara 633-0062 (JP)
- Kaneko, Yuriko
Nara-shi, Nara 631-0804 (JP)
- Takeda, Mamoru
Soraku-gun, Kyoto 619-0237 (JP)

(74) Representative:
Eisenführ, Speiser & Partner
Martinistrasse 24
28195 Bremen (DE)

Remarks:
A request for correction of minor clerical errors has been filed pursuant to Rule 88 EPC. A decision on the request will be taken during the proceedings before the Examining Division (Guidelines for Examination in the EPO, A-V, 3.).

(54) High-pressure discharge lamp and manufacturing method thereof

(57) An object is to provide a method for manufacturing a high-pressure discharge lamp (500) of the double-ended type having excellent resistance to high pressure and wherein the internal diameter (W) of the portion where the light-emitting section and side tube are adjacent can be reduced without restricting the maximum diameter (L) of the electrode on the side where it projects into the light-emitting section (3). An electrode assembly (105) is arranged within evacuated a glass bulb (2) such that the end of the electrode (102) where a coil (102b) is wound onto it is positioned within the light-emitting section (3). In this condition, the portion where the light-emitting section (3) and the side tube (4a,4b) are adjacent is heated by a burner (300). The internal diameter of the side tube (4a,4b) can thereby be formed with reduced-diameter section (7) which is not smaller than that of the electrode rod (102a) without restricting the diameter at the location of coil (102b).

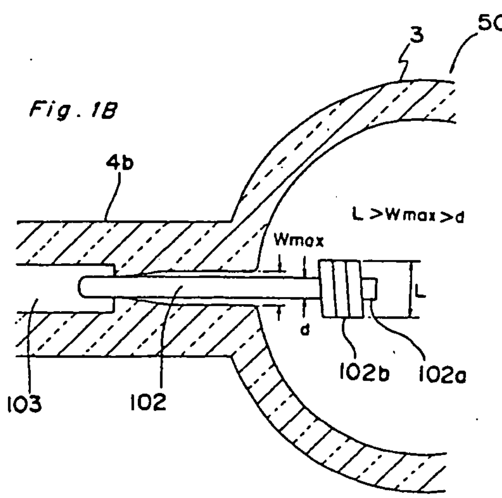


Fig. 1B

EP 0 866 488 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a double-ended high-pressure discharge lamp and method of manufacturing it.

2. Description of the Related Art

In recent years, liquid crystal projectors etc. have become well known as means for displaying enlarged projected images of letters and drawings etc. Since such image projection devices require a prescribed optical output, high-pressure discharge lamps of high luminance are usually employed as the light source. Typically such a lamp is combined with a reflecting mirror. Recently, in order to improve the convergence of the reflecting mirror, shortening of the arc length of the high-pressure discharge lamp is being demanded. However, such shortening of the arc length is associated with a drop in the lamp voltage, so if it is desired to operate with the same lamp power, lamp current must be increased. Increasing the lamp current leads to increased electrode loss and activates evaporation of the electrode material, resulting in early deterioration of the electrode i.e. tends to shorten the life of the lamp. For these reasons, if the arc length is to be shortened, usually the mercury vapour pressure etc. during lamp operation is increased, in order to avoid a drop in lamp voltage (increase in lamp current).

If the mercy vapour pressure etc. during lamp operation is increased, it is necessary to construct the lamp in such a way that it will not break under this high operating pressure. A powerful means for preventing such lamp breakage is disclosed at page 111 of the Symposium Proceedings of The 7th International Symposium on the Science and Technology of Light Sources (1995). An outline of the details of this disclosure will be given using Fig. 7A and 7B.

Fig. 7A shows the construction of a prior art high-pressure discharge lamp 130. 100 is a practically spherical light-emitting section made of quartz glass and 101 are side tubes likewise made of quartz glass extending from light-emitting section 100. 102 are tungsten electrodes, 103 are molybdenum foils, and 104 are molybdenum external leads; these constitute electrode assemblies 105 wherein electrode 102 at one end of molybdenum foil 103 projects into light-emitting section 100 and the other end of molybdenum foil 103 is connected to molybdenum external lead 104; sealing in airtight manner is effected at the location of molybdenum foil 103 onto side tubes 101. Electrodes 102 comprise a tungsten electrode rod 102a of diameter 0.9 mm and a tungsten coil 102b wound onto electrode rod 102a in the vicinity of the end that projects into light-emitting section 100. The external diameter L of electrode 102 with coil 102b wound onto it is about 1.4 mm. Sealed-in material 120 comprising mercury or metal halide and argon gas (not shown) is sealed into light-emitting section 100.

Fig. 7B is a cross-sectional view taken along a line VIIB-VIIB shown in Fig. 7A. Essentially it is not possible to achieve perfect adhesion between tungsten electrode 102 and quartz glass, so a non-adhering part 107 is produced around electrode 102. The width of this non-adhering part 107 is indicated by W. Such a cross-sectional view can be observed at any arbitrary cross-section in the range AA' of Fig. 7A i.e. from about the boundary of light-emitting section 100 and side tube 101 to the end of molybdenum foil 103 (on the side where electrode 102 is connected).

In Fig. 7A, if the pressure within light-emitting section 1 when lamp 130 is operated is P (pressure P acts generally in the direction of the arrow 160 in light-emitting section 100), as shown by arrow 170 in Fig. 7B, a pressure Pmax (>P) larger than the pressure P generally indicated by arrow 160 acts on this non-adhering part 107 (stress concentration phenomenon). Consequently, even if the pressure P within light-emitting section 1 when the lamp 130 is operated is smaller than the breaking strength Plimit (considered to be about 400 atmospheres to 600 atmospheres. This breaking strength decreases if application of pressure is continued for a long time) of the glass that forms the light-emitting section, it is possible for a pressure exceeding the breaking strength of the glass to act at non-adhering part 107 (Pmax > Plimit > P). If this happens, the glass of non-adhering part 107 breaks and lamp 130 is destroyed.

According to the disclosure, the magnitude of the pressure Pmax acting on non-adhering part 107 generally indicated by arrow 170 due to stress concentration increases in proportion to the square root of the width W of non-adhering part 107 ($P_{max} \propto P \times W^{1/2}$). Consequently, if for example a pressure P of the same magnitude within light-emitting section 1 is considered, reducing the width W of non-adhering part 107 reduces the pressure Pmax acting on non-adhering part 107 and so increases the margin (Plimit - Pmax) in respect of the breakage strength Plimit of the glass, resulting in a lamp which is less likely to be destroyed (as described above the breaking strength Plimit decreases if pressure continues to be applied to the glass for a long period so some such margin is necessary to avoid a lamp that is operated at high pressure when operated being destroyed over a long period).

Conversely if the width of non-adhering part 107 is not changed, and lamp 130 is operated with high pressure P within light-emitting section 1, since the pressure Pmax acting on non-adhering part 107 is large, the margin (Plimit - Pmax) with respect to the breaking strength Plimit of the glass becomes small, so the lamp can easily be destroyed.

From another point of view, considering the margin

(Plimit - Pmax) with respect to a glass breaking strength Plimit of the same size, if the width W of the non-adhering part 107 is decreased the pressure P within light-emitting section 1 may be allowed to have correspondingly larger values. That is, lamp 130 can be operated (lit) with higher pressure.

Due to the above, the extent to which stress concentration can be reduced by decreasing width W of this non-adhering part 107 is a vital point in preventing destruction when the lamp operating pressure is made high.

Conventionally therefore lamps were manufactured in which the width W of the non-adhering part 107 was reduced by a method as disclosed in for example Early Japanese Patent Publication H. 7-262967 in order to prevent destruction of the lamp when this was operated with raised pressure in order to shorten the arc length. This prior art method of manufacture is described below.

Figs. 8A, 8B, 8C and 8D are views given in illustration of an outline of the conventional method of manufacture of a high-pressure discharge lamp 130.

A prescribed light-emitting section 100 is formed by thermally expanding a quartz glass tube constituted by a glass bulb 110 in Fig. 8A manufactured in a separate process. Side tubes 101 are constituted by undeformed quartz glass attached to both ends of light-emitting section 100. Whilst rotating this glass bulb 110 as shown by arrow 115 on a rotatable chuck, not shown, that grips both ends of side tubes 101, the boundary regions of light-emitting section 100 and side tubes 101 are heated by burners generally shown by arrows 111. Reduced-diameter sections 113 indicated by the shaded regions in which the internal diameter at that location is smaller are formed by applying pressure to softened locations of side tubes 101 by means of freely rotating carbon heads 112.

After reduced-diameter sections 113 have been formed in the vicinity of both ends of light-emitting section 100 as described above, next, as shown in Fig. 8B, electrode assemblies 105 are inserted into side tubes 101 such that one end of electrode 102 constituting part of electrode assembly 105 is positioned within light-emitting section 100. Then, by heating the locations of molybdenum foil 103 to soften the glass sufficiently by means of burners generally indicated by arrows 131 over a suitable length from the vicinity of reduced-diameter section 113 (near the molybdenum foil 103) to external leads 104, the electrode assemblies 105 are sealed onto the side tube 101 by clamping with a pair of clamping elements, not shown, or by compressing to a flattened shape. Molybdenum foil 103 of thickness about 20 micron expands filling up the gap with the glass so that gas-tightness is maintained at the location of the molybdenum foil 103.

Next, as shown in Fig. 8C, material 120 for sealing-in is inserted into light-emitting section 100 from side tubes 101 which are currently as yet unsealed and electrode assemblies 103 are then inserted into side tubes 101. In this condition, just as in Fig. 8B, the side tubes from reduced-diameter sections 113 to external leads 104 are softened by heating with burners, generally indicated by arrows 121, and the electrode assemblies 105 are sealed onto the side tube 101 by clamping with a pair of clamping elements, not shown, or by compressing to a flattened shape to complete the conventional high-pressure discharge lamp 130 shown in Fig. 8D in the same way as in Fig. 7A.

Fig. 9 is a detail view of the vicinity of the boundary (portion A of Fig. 7A or Fig. 8D) of light-emitting section 100 and side tube 101 of a conventional lamp 130. As described above, since essentially it is not possible to achieve perfect adhesion between tungsten electrode 102 and quartz glass, a gap with respect to the glass is formed around the periphery of electrode 102(non-adhering part 107 in Fig. 7B). As shown in Fig. 9, the width of this gap is not uniform, but in the case of a lamp manufactured by the conventional method of manufacture described above, the gap is largest in the vicinity of the boundary of light-emitting section 100 and side tube 101 and diminishes towards molybdenum foil 103. Its greatest width is called Wmax. The greatest pressure (concentrated stress) Pmax ($\propto$ $Wmax^{1/2}$) acts where this width is largest.

In the prior art method of manufacture disclosed in Early Japanese Patent Publication H. 7-262967 described above, electrode assemblies 105 are inserted from side tubes 101 after diameter reduction of the boundary region of light-emitting section 100 and side tube 101 to form reduced-diameter sections 113 and one end of electrodes 102 must be positioned within light-emitting section 100. Consequently, lamps can only be manufactured wherein the width Wmax of the gap (non-adhering part 107) in the vicinity of the boundary of light-emitting section 100 and side tube 101 is always larger (Wmax > L) than the diameter L = 1.4 mm (>d) of the location where coil 102b is wound onto electrode rod 102a of the greatest diameter on the side projecting into light-emitting section 100 of electrode 102 i.e. diameter d = 0.9 mm. Consequently in a conventional high-pressure discharge lamp 130 there was the problem that, since a construction was adopted in which Wmax > L, the pressure Pmax acting on non-adhering part 107 could not be made sufficiently small, making the lamp liable to fail.

To take a specific numerical example, in the case of a lamp 130 manufactured by the conventional method in which the electrode rod 102a was of diameter d = 0.9 mm and the external diameter in the portion where the coil 102b was wound was L = 1.4 mm, the maximum width Wmax of the gap between electrode 102 and the glass constituting side tube 101 was about 1.5 mm. In this case if a small hole is provided in light-emitting section 100 and the pressure within light-emitting section 100 is increased by feeding high-pressure gas in from this hole, destruction of lamp 130 is caused when the

pressure of the high-pressure gas fed into light-emitting section 100 reaches about 120 atmospheres.

As to the lamp formed by electrode 102 having electrode rod 102a but having no coil 102b, an internal diameter rw of the reduced-diameter section 113 shown Fig. 8A, can only be reduced to d+Δd (d=diameter of electrode rod 102a). According to the present technology Δd is equal to 0.4mm, but Δd can be as small as 0.1mm. Theoretically the internal diameter rw can be made smaller than d+0.4mm, such as to d+0.1mm, but practically, from the view point of the present technology, the internal diameter rw is preferably d+0.4mm as explained below.

When the internal diameter rw is made smaller than d+0.4mm, a gap between the glass and the electrode 102 (electrode rod 102a) becomes so small that it will be very difficult to insert the electrode 102 (electrode rod 102a) through the reduced-diameter section 113, resulting in low productivity. Furthermore, when the internal diameter rw is made small, it will be very difficult to insert the material 120 in the light-emitting section 100. However, when the technology for inserting the electrode 102 (electrode rod 102a) as well as the material 120 is improved, the internal diameter rw can be made as small as d+0.1mm.

It is an object of the present invention to solve the above problems and to provide a high-pressure discharge lamp of the double-ended type having a construction that is not liable to failure and a method of manufacturing it.

SUMMARY OF THE INVENTION

In order to achieve the above object, according to the present invention there is provided a method for manufacturing a high-pressure discharge lamp having a center glass bulb defining a light-emitting section and side tubes extending on both sides thereof, an electrode assembly sealed in each of said side tubes, said electrode assembly having an electrode and a metal foil with the electrode connected to one end, said method comprising: inserting said electrode assembly such that one end of the electrode which is not connected to the metal foil is positioned in the light-emitting section; and reducing the internal diameter of the tube surrounding the electrode.

Also the step of reduction of the internal diameter of the side tube surrounding the electrode is performed by the mode of substantially uniformly heating the side tube and compressing it from the outside.

Alternatively the internal diameter of the side tube surrounding the electrode is reduced by maintaining the interior of the glass bulb in which the electrode assembly is inserted in a condition below atmospheric pressure and heating the side tube surrounding the electrode substantially uniformly.

Also the step of reduction of the internal diameter of the side tube surrounding the electrode is performed by the mode of forming built-up thickness of the glass by heating the side tube substantially uniformly and performing mutual approach and separation movement of the side tube and the light-emitting section.

Also in a high-pressure discharge lamp according to the present invention, the maximum width Wmax of the gap between the electrode and the glass present around the electrode in the interval from the junction of the electrode and the metal foil to the boundary region of the light-emitting section and the side tube is $d < Wmax < L$ wherein the maximum diameter of the electrode is L and its minimum diameter is d.

When the electrode is made of a rod having a diameter d and without having a coil, the maximum width Wmax is $d < Wmax < d+\Delta d$, wherein $0.1mm \leq \Delta d \leq 0.4mm$.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is views showing the construction of a high-pressure discharge lamp according to a first embodiment of the present invention;

Fig. 1B is an enlarged view of a portion of the high-pressure discharge lamp of Fig. 1A;

Figs. 2A, 2B, 2C, 2D 2E and 2F are views showing the construction steps of a high-pressure discharge lamp according to a second embodiment of the present invention;

Fig. 3 is a view showing a step of reducing the diameter of a boundary region of a light-emitting section and side tube according to the present invention;

Fig. 4 is a view showing a step of reducing the diameter of a boundary region of a light-emitting section and side tube according to the present invention;

Fig. 5 is a view showing a method of fixing an electrode assembly;

Figs. 6A, 6B, 6C and 6D are views showing construction steps of a high-pressure discharge lamp according to a third embodiment of the present invention;

Figs. 7A and 7B are views showing the construction of a prior art high-pressure discharge lamp;

Fig. 8 is views showing a method of manufacturing a prior art high-pressure discharge lamp; and

Fig. 9 is a detail view of the boundary region of a light-emitting section and side tube of a prior art high-pressure discharge lamp.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention are described in detail below with reference to the drawings.

(First Embodiment)

A first embodiment of a high-pressure discharge lamp according to the present invention is described below using the drawings.

Figs. 1A and 1B are views showing a high-pressure discharge lamp 500 according to a first embodiment of the present invention.

In Fig. 1, reference number 3 is a light-emitting section consisting of glass, and 4a, 4b are side tubes consisting of glass that extend respectively from light-emitting section 3 and wherein are sealed a pair of electrode assemblies 105 of the same construction and shape as in the case of the prior art high-pressure discharge lamp. Within light-emitting section 3, just as in the case of the prior art high-pressure discharge lamp, there is sealed sealed-in material 120 consisting of mercury and/or metal halide.

Fig. 1B is a detail view of the boundary region of light-emitting section 3 and side tube 4b (or 4a) in Fig. 1A.

The construction of lamp 500 of this first embodiment is characterised in that the maximum width of the gap between electrode 102 and the glass constituting side tube 4b (or 4a) at the region of the boundary of light-emitting section 3 and side tube 4b (or 4a) is smaller than the diameter L = 1.4 mm (> d) at the part of electrode 102 which is of maximum diameter on the side projecting into light-emitting section 3 i.e. the part where coil 102b is wound onto electrode rod 102a of diameter d = 0.9 mm (L > Wmax > d).

Taking specific numerical values, the maximum width Wmax of the gap between electrode 102 and the glass constituting side tube 4b(or 4a) is about 0.95 mm for an external diameter L = 1.4 mm of the part where coil 102b is wound onto electrode rod 102a of diameter d = 0.9 mm.

In order to confirm the strength of lamp 500 of this embodiment in respect of cracking, a small hole was formed in light-emitting section 3, the pressure within light-emitting section 3 was increased by feeding high-pressure gas in from this hole and the pressure at which the lamp broke was measured. As a result it was found that the lamp 500 broke in the vicinity of the high-pressure gas that was fed into light-emitting section 3 reaching a pressure of about 160 atmospheres.

Comparing this result and the result that the prior art lamp 130 having external diameter L = 1.4 mm of the part where coil 102b is wound onto electrode rod 102a of the same diameter d = 0.9 mm broke in the vicinity of the pressure of the high-pressure gas fed into the light-emitting section reaching a pressure of about 120 atmospheres, it can be seen that the lamp of this first embodiment, which is substantially the same as the prior art lamp 130 in regard to the rest of its construction (the operation and/or light-emitting performance etc. of lamp 500 of this first embodiment are therefore exactly the same as those of the prior art lamp 130) except for the fact that the maximum width Wmax of the gap between electrode 102 and the glass constituting the side tube is smaller, is a lamp which is more difficult to break.

Thus, as described above, with a lamp according to the first embodiment, since it has a construction wherein the maximum width Wmax of the gap between electrode 102 and the glass constituting the side tube is smaller than the maximum diameter of electrode 102 on the side where it projects into light-emitting section 3 i.e. the diameter L (> d) of the part where coil 102b is wound onto electrode rod 102a of diameter d (L > Wmax > d), it has the characteristic that the stress concentration acting at the non-adhering part at the periphery of electrode 102 is smaller than for the prior art lamp (Wmax > L) having an electrode 102 of the same construction and so is less liable to cracking.

The following embodiments are examples of the manufacture of a high-pressure discharge lamp according to the present invention as illustrated in the first embodiment.

(Second Embodiment)

Figs. 2A to 2F are views given in explanation of a second embodiment of a method of manufacturing a high-pressure discharge lamp according to the present invention.

2 in Fig. 2A is a glass bulb manufactured in a separate step and is constituted of a light-emitting section 3 that is formed in a prescribed shape by heating and thermal expansion of a quartz glass tube and side tubes 4a, 4b consisting of quartz glass tubes extending from the side ends of light-emitting section 3. The end of one side tube 4a is sealed. The two ends of side tubes 4a, 4b of this glass bulb 2 are held so as to be capable of rotation and of being made to approach or recede from each other by means of a chuck 1.

Next, as shown in Fig. 2B, electrode assembly 105 which is identical with that shown in Fig. 1 is inserted into side tube 4b such that the end part, on which is wound coil 102b of electrode 102 constituting a part thereof, is arranged within light-emitting section 3. In this condition, as shown by the arrow 6, glass bulb 2 is rotated by chuck 1. Then, as shown by arrow 5a, the interior of glass bulb 2 is evacuated, and argon gas of pressure 200 mbar is sealed therein as generally indicated by arrow 5a. The vicinity of the end of side tube 4b which is not yet sealed is then sealed by heating with a burner 200, generally shown by arrow 200.

Next, as shown in Fig. 2C, the interval between the boundary region of light-emitting section 3 and side tube 4b and the junction of electrode 102 and molybdenum foil 103 is now heated and softened over an appropriate length by means of a burner constituting a heating element and generally indicated by arrow 300.

Since in this process the pressure within glass bulb 2 is below atmospheric, as the heated part is softened,

the internal diameter of side tube 4b at the location where the heating takes place is reduced.

As best shown in Fig. 2D, heating by burner 300 is stopped at the point where the internal diameter of side tube 4b has shrunk to rw which is, at most, smaller than the diameter L of the location where coil 102b of electrode 102 is wound on and is preferably approximately in the vicinity of the diameter d of electrode rod 102a constituting electrode 102. A reduced-diameter section 7 is thus formed (see the detail view).

Next, as shown in Fig. 2E, heating is performed by the burner generally indicated by arrow 300 over a suitable length from the vicinity of reduced-diameter section 7 (near molybdenum foil 103) as far as external lead 104 in order to sufficiently soften the glass at the location of molybdenum foil 103. Since in this process the pressure within glass bulb 2 is below atmospheric, as the heated part is softened, the internal diameter of side tube 4b at the location where the heating takes place is reduced. When sufficient reduction in diameter has taken place to maintain air-tightness at molybdenum foil 103, heating is discontinued, completing the air-tight sealing of electrode assembly 105 at the side tube 4a.

Next, as shown in Fig. 2F, the sealed end of side tube 4a is opened by being cut off and, from this, sealed-in material 120 such as mercury and/or metal halide is inserted into light-emitting section 3 and simultaneously the rest of electrode assembly 105 is arranged within side tube 4a just as in Fig. 2E. In this condition, glass bulb 2 is rotated by chuck 1 as shown by the arrow 6. Then, as shown by arrow 5a, the interior of glass bulb 2 is evacuated and argon gas at a pressure of 200 mbar is sealed therein as generally shown by arrow 5b. The vicinity of the open end of tube 4a is then sealed by heating using burner 200 as generally shown by arrow 200.

After this, as shown in Fig. 2C and Fig. 2E, the interval between the boundary of light-emitting section 3 and side tube 4a and the junction of electrode 102 and molybdenum foil 103 is now heated and softened over an appropriate length using a heating element constituted by a burner generally indicated by arrow 300 so as to form a reduced-diameter section 7 by shrinking the internal diameter of side tube 4a about as far as the diameter of electrode rod 102a constituting electrode 102; the glass is then heated and softened over an appropriate length from the vicinity of reduced-diameter section 7 (from molybdenum foil 103) as far as external lead 104 to thereby perform air-tight sealing of electrode assembly 105.

If, after reducing the diameter of the boundary region of light-emitting section 3 and side tube 4a and sealing a pair of electrode assemblies 105 into side tubes 4a, 4b, the ends of side tubes 4a, 4b are cut off and removed such that external leads 104 do not project to the outside, a high-pressure discharge lamp 500 according to the first embodiment as shown in Fig. 1 is finally obtained.

It should be noted that, in the second embodiment, in order to achieve reliable air-tight sealing of the pair of electrode assemblies 105 in side tubes 4a, 4b, particularly at the location of molybdenum foil 103, it would be possible, when the glass (side tubes 4a, 4b) is softened, to seal electrode assemblies 105 in side tubes 4a, 4b by gripping with a pair of gripping elements or clamping flat by applying pressure.

Further, while in the second embodiment in effecting air-tight sealing of electrode assemblies 105, the region of molybdenum foil 103 was sufficiently heated and softened after forming reduced-diameter section 7, if reduced-diameter section 7 is formed after inserting electrode assemblies 105 into side tubes 4a, 4b, reduced-diameter section 7 could be formed for example by reducing the diameter of side tube 4a (or 4b) by heating the vicinity of the boundary of light-emitting section 3 and side tube 4a (or 4b) after sufficiently heating and softening the region of molybdenum foil 103 to complete air-tight sealing.

Also when the reduced-diameter section is formed in the vicinity of the boundary of light-emitting section 3 and side tube 4a in a condition with sealed-in material 120 already inserted or when a electrode assembly 105 is sealed into side tube 4a, in order to prevent sealed-in material 120 from being evaporated by the heat of the burner, there would be no problem in the addition of cooling of part of light-emitting section 3 by for example blowing liquid nitrogen onto it.

In Fig. 2C, even without a burner 300, there would be no problem in moving burner 200 to provide the heating element used for forming reduced-diameter section 7.

And in Fig. 2C, at the stage of forming reduced-diameter section 7, in order to assist the diameter reduction of the internal diameter of tube 4b, reduced-diameter section 7 could be formed by compressing the heated portion by means of freely rotatable heat-resistant carbon roller 77 for example as shown in Fig. 3. In this case, there could be a plurality of carbon heads 77 for forming reduced-diameter section 7 and reduced-diameter section 7 could be formed in a mode such that compression is effected at a plurality of locations on the periphery of the part where reduced-diameter section 7 is to be formed.

Alternatively as shown in Fig. 4, when the glass has softened, by making light-emitting section 3 and side tube 4b gradually approach each other whilst executing approach and separation movement by mutual movement of chucks 1 as shown by arrow 30, built-up thickness portions of the glass can be formed in the locations where softening has occurred. Such built-up thickness portions of the glass grow towards the interior, so they assist diameter reduction of side tube 4b.

In the second embodiment above, an example was described in which in order to heat side tubes 4a, 4b uniformly, glass bulb 2 was rotated; however, it would be possible, instead of rotating glass bulb 2, to adopt a con-

struction in which burner 300 is arranged to rotate in the circumferential direction about the side tube or to adopt a construction in which the periphery of the side tube is heated by a plurality of burners.

In the second embodiment a case was described in which electrode assemblies 105 were fixed and arranged within side tubes 4a, 4b. Whether or not electrode assemblies 105 are held within side tubes 4a, 4b has no effect on the benefits of the present invention but, as shown for example in Fig. 5, by connecting thin metal foils 78 of for example molybdenum bent such that their overall length h is slightly larger than the internal diameter D of side tube 4b (or 4a) and inserting them in side tubes 4b (or 4a) at one end of external lead 104, positional alignment of electrode assemblies 105 could be effected by frictional coupling of the portions where metal foils 78 are bent and the side tube 4b (or 4a). In this case, the further benefit is obtained that the accuracy of arrangement within light-emitting section 3 and/or the inter-electrode distance can be improved.

(Third Embodiment)

Next, a third embodiment of a method of manufacturing a high-pressure discharge lamp according to the present invention is described with reference to Figs. 6A to 6D.

In Fig. 6A, 50 has joined to it a comparatively fine quartz glass tube 40 for evacuating the interior of light-emitting section 3 of glass bulb 2 and inserting the material 120 into light-emitting section described in the second embodiment. This glass tube 40 for evacuation and insertion is held by a chuck 60 and bulb 50 is arranged such that side tubes 4a, 4b extend in the vertical direction.

Next as shown in Fig. 6B, an electrode assembly 105 is inserted into the side tube 4b that is positioned on the lower side such that the end on which coil 102b of electrode 102 constituting part thereof is wound is arranged within light-emitting section 3. The positional relationship of electrode assembly 105 and side tube 4b is then fixed by holding external lead 104 by chuck 61. Also, as shown by the arrow 43, inert gas consisting of argon gas is introduced from evacuation glass tube 43. In this condition a pair of burners 44a, 44b are lit and side tube 4b is heated whilst rotating these about the circumference, centered on side tube 44b. In this process, at least one of the burners 44a, 44b (burner 44b in Fig. 6B) is arranged such that the boundary region of side tube 4b and light-emitting section 3 is heated.

First of all, when the boundary region of side tube 4b and light-emitting section 3 has become soft, this part is subjected to pressure by a carbon head 62 so that the internal diameter of the side tube 4a (or 4b) at this part is reduced. This carbon head 62 is rotated about side tube 4b in the same way as burners 44a, 44b.

Just as in the case of Fig. 2D, compression of side tube 4b by carbon head 62 is discontinued at the point where the internal diameter rw of side tube 4b has shrunk to, at most, smaller than the diameter L of the location where coil 102b of electrode 102 is wound on and preferably to approximately in the vicinity of the diameter d of electrode rod 102a constituting electrode 102. Formation of reduced-diameter section 7 is thus completed.

Then, as shown in Fig. 6C, after the location of molybdenum foil 103 has reached a sufficiently heated condition, heating by burners 44a and 44b and rotation of burners 44a, 44b and carbon head 62 are now discontinued and, as shown by arrow 63, side tube 4b is immediately gripped in the thickness direction of molybdenum foil 103 constituting a part of electrode assembly 105 and compressed by a pair of heat-resistant blocks 45 so that electrode assembly 105 is sealed in air-tight manner into side tube 4a (or 4b).

Next, the holding by chuck 61 is released and glass bulb 50 vertically inverted so that formation of reduced-diameter section 7 and air-tight sealing of electrode assembly 105 can be effected in respect of the remaining side tube 4a. Thereupon, as shown in Fig. 6D, a glass bulb 70 is completed which has a construction wherein, just as in the case of the high-pressure discharge lamp 500 according to the first embodiment of the present invention, the maximum width Wmax (Fig. 1B) of the gap between electrode 102 and glass constituting the side tube is smaller than the maximum diameter of electrode 102 on the side where it projects into light-emitting section 3 i.e. the diameter L (> d) of the location where coil 102b is wound onto electrode rod 102a of diameter d (L > Wmax > d).

After this, although not shown in the drawings, sealed-in material 120 is introduced into light-emitting section 3 from evacuation glass tube 40 and light-emitting section 3 is evacuated, a prescribed amount of sealed-in gas inserted in light-emitting section 3 and evacuation glass tube 40 is sealed off. In this way, a high-pressure discharge lamp of the double-ended type identical to the high-pressure discharge lamp 500 shown in Figs. 1A and 1B can be obtained having the characteristics that the stress concentration acting at the non-adhering part created around the circumference of electrode 102 is smaller than in the case of a prior art lamp (Wmax > L) having an electrode 102 of the same construction and therefore that it is less liable to breakage.

Although in this embodiment a pair of rotating burners were employed the number of burners is not restricted to this. Also a method could be adopted in which formation of reduced-diameter section 7 and air-tight sealing of electrode assembly 105 are performed by inserting electrode assembly 105 into the side tube 4a (or 4b) positioned above.

Also, reduced-diameter section 7 could be formed in a mode in which there are a plurality of carbon heads 62 for forming reduced-diameter section 7, such that

compression is effected at a plurality of locations of the circumference of the part which reduced-diameter section 7 is to be formed.

It should noted that, although in the second and third embodiments examples were described in which the shape of side walls 4a, 4b of glass bulb 2 formed in the stage previous to the diameter reduction was a straight tube, if one end of the side where coil 102b is wound onto electrode 102 can be arranged within light-emitting section 3, a shape could be adopted in which the rest of the shape, for example the portion where the light-emitting section and side tube are adjacent, is of reduced diameter from the beginning. In this case, the further benefit is obtained that positional alignment of the tip of electrode 102 within light-emitting section 3 is facilitated.

Also there are no restrictions on the shape of electrode rod 102a and coil 102b constituting electrode 102 and electrode 102 could be of a construction in which electrode rod 102a and coil 102b are integrally formed. Further, there are no problems if external lead 104 is connected to one end of molybdenum foil 103 at the stage of formation of reduced-diameter section 7.

Also, although in the second and third embodiments examples were described in which burners were employed as the heating element for heating the glass, other types of heating element such as for example radio-frequency inductive heating elements and/or lasers could be employed. Radio-frequency inductive heating elements and/or lasers do not require oxygen, so a manufacturing step comprising heating can be performed in an atmosphere of a dried inert gas, so the further benefit is obtained that admixture of impurities (moisture) into the lamp can be prevented thus extending the life of the lamp.

Also, although in the second and third embodiments examples were so described that the electrode 102 is formed by electrode rod 102a and coil 102b, but the present invention is also applicable to the electrode which has no coil 102b, but only the electrode rod 102a. After the electrode 102 (electrode rod 102a) and material 120 are inserted in the light-emitting section 3, it is possible according to the present invention to reduce the internal diameter rw of the reduced-diameter section 7 less than $d+\Delta d$ (d = diameter of electrode rod 102a), wherein $0.1mm \leq \Delta d \leq 0.4mm$, and preferably $\Delta d=0.4mm$.

Preferred embodiments of the present invention have been described above but this description is not imitative and various modifications are of course possible. The method of manufacturing and lighting a high-pressure discharge lamp according to the present invention illustrated in the embodiments is by way of example; the scope of the invention is determined by the claims.

As described above with reference to embodiments, according to the present invention, the internal diameter of a side tube enclosing an electrode is reduced in a condition in which an electrode assembly is inserted in the side tube, so the internal diameter of the side tube can be reduced to the diameter of the electrode positioned in the reduced diameter part; consequently an excellent high-pressure discharge lamp of the double-ended type which is resistant to breakage can be provided.

Claims

1. A method for manufacturing a high-pressure discharge lamp having a center glass bulb defining a light-emitting section and side tubes extending on both sides thereof, an electrode assembly sealed in each of said side tubes, said electrode assembly having an electrode and a metal foil with the electrode connected to one end, said method comprising:

   inserting said electrode assembly such that one end of the electrode which is not connected to the metal foil is positioned in the light-emitting section; and
   reducing the internal diameter of the tube surrounding the electrode.

2. The method according to claim 1, wherein the step of reduction of the internal diameter of the side tube surrounding the electrode is performed by the mode of substantially uniformly heating the side tube surrounding the electrode and compressing the side tube surrounding the electrode from the outside.

3. The method according to claim 1, wherein the internal diameter of the side tube surrounding the electrode is reduced by maintaining the interior of the glass bulb in a condition below atmospheric pressure and heating the side tube surrounding the electrode substantially uniformly.

4. The method according to claim 1, wherein the step of reduction of the internal diameter of the side tube surrounding the electrode is performed by the mode of forming built-up thickness of the glass in the side tube surrounding the electrode by heating the side tube surrounding the electrode substantially uniformly and performing mutual approach and separation movement of the side tube and the light-emitting section.

5. The method according to claim 2, wherein the step of reduction of the internal diameter of the side tube surrounding the electrode is performed by the mode of inserting inert gas into the side tube in order to prevent oxidation of the electrode assembly of which the electrode constitutes a part.

6. The method according to claim 5, wherein the inert gas is argon gas.

7. The method according to claim 2, wherein the side tube is heated whilst being rotated in the circumferential direction in order to achieve substantially uniform heating of the side tube surrounding the electrode.

8. The method according to claim 2, wherein the heating element that heats the side tube is rotated in the circumferential direction of the tube in order to achieve substantially uniform heating of the side tube surrounding the electrode.

9. The method according to claim 2, wherein the heating element that heats the side tube that surrounds the electrode is a burner.

10. The method according to claim 2, wherein the heating element that heats the side tube that surrounds the electrode is a radio-frequency inductive heating element.

11. The method according to claim 2, wherein the heating element that heats the side tube that surrounds the electrode is a laser.

12. The method according to claim 1, wherein the electrode that constitutes the electrode assembly is of larger diameter on the side that projects into the light-emitting section than its diameter on the side where the metal foil is connected.

13. A high-pressure discharge lamp of the double-ended type comprising:

(1) a light-emitting section made of glass;
(2) side tubes made of glass extending from both ends of the light-emitting section; and
(3) a pair of electrodes each electrode having one end arranged within the light-emitting section and the other end connected to a metal foil, said each electrode being sealed in air-tight manner in the side tube wherein the maximum width Wmax of the gap between the electrode and the glass present around the electrode in the interval from the junction of the electrode and the metal foil to the boundary region of the light-emitting section and the side tube is $d < Wmax < L$ wherein the maximum diameter of the electrode is L and its minimum diameter is d.

14. A high-pressure discharge lamp of the double-ended type comprising:

(1) a light-emitting section made of glass;
(2) side tubes made of glass extending from both ends of the light-emitting section; and
(3) a pair of electrodes each electrode having one end arranged within the light-emitting section and the other end connected to a metal foil, said each electrode formed by a rod having a diameter d, said each electrode being sealed in air-tight manner in the side tube wherein the maximum width Wmax of the gap between the electrode and the glass present around the electrode in the interval from the junction of the electrode and the metal foil to the boundary region of the light-emitting section and the side tube is $d < Wmax < d+\Delta d$.

15. The high-pressure discharge lamp according to claim 1, wherein $0.1mm \leq \Delta d \leq 0.4mm$.

16. The high-pressure discharge lamp according to claim 1, wherein $\Delta d = 0.4mm$.

Fig. 1A

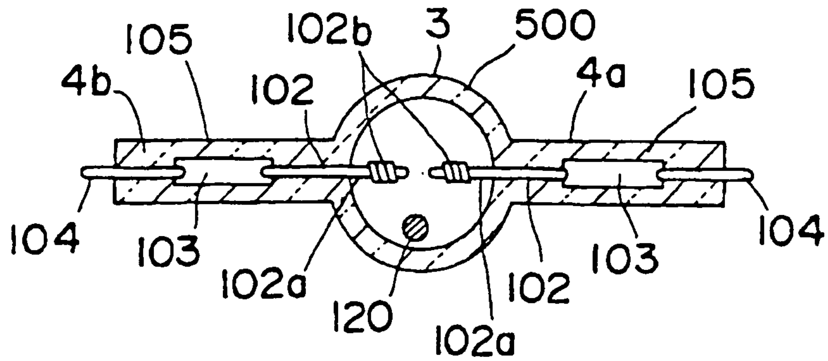
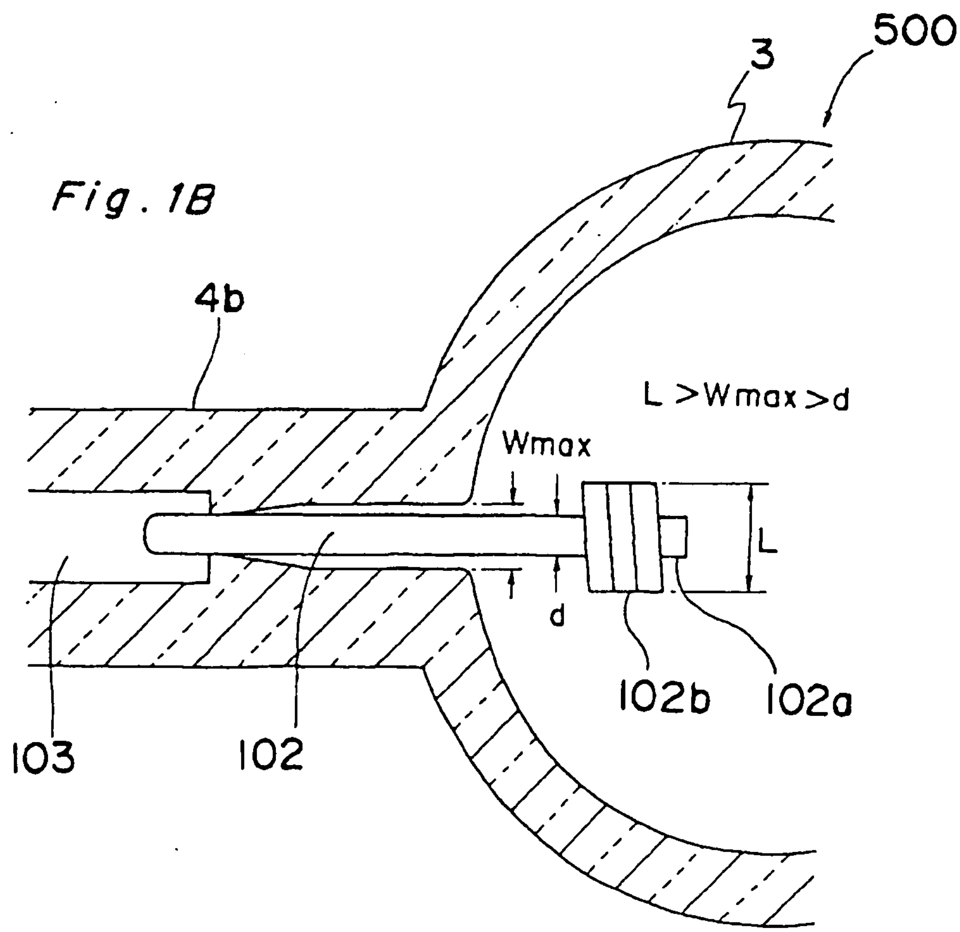

105
102b
3
500
4b
102
4a
105
104
103
102a
120
102
103
104
102a

Fig. 1B


3
500
4b
L >Wmax>d
Wmax
L
d
102b
102a
103
102

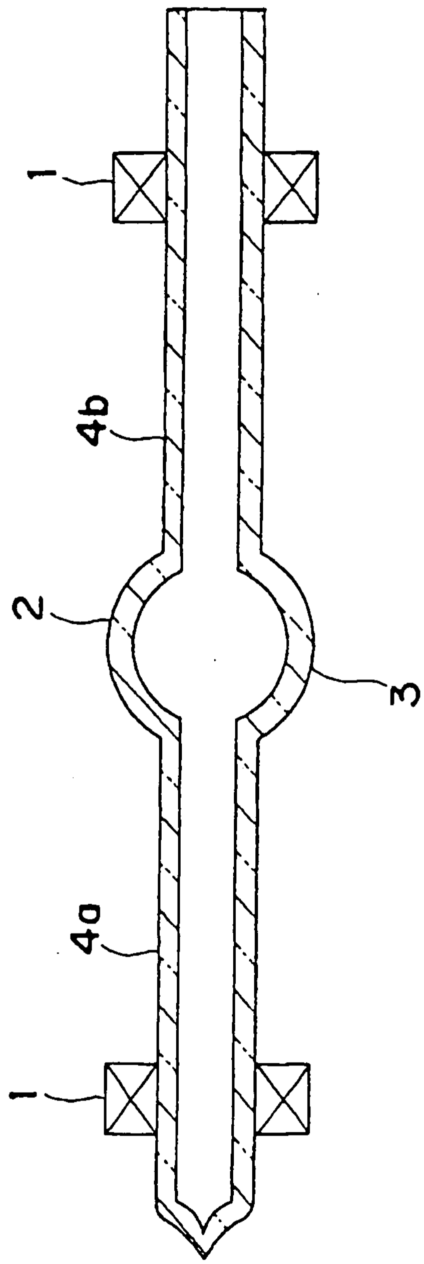


Fig. 2A

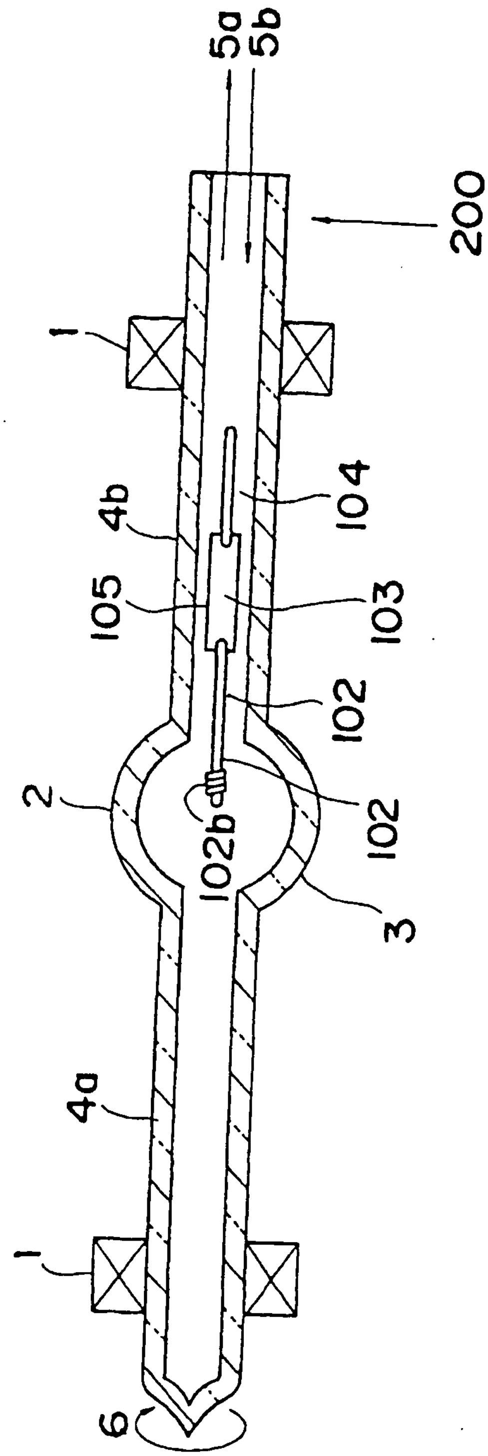


Fig. 2B

Fig. 2C

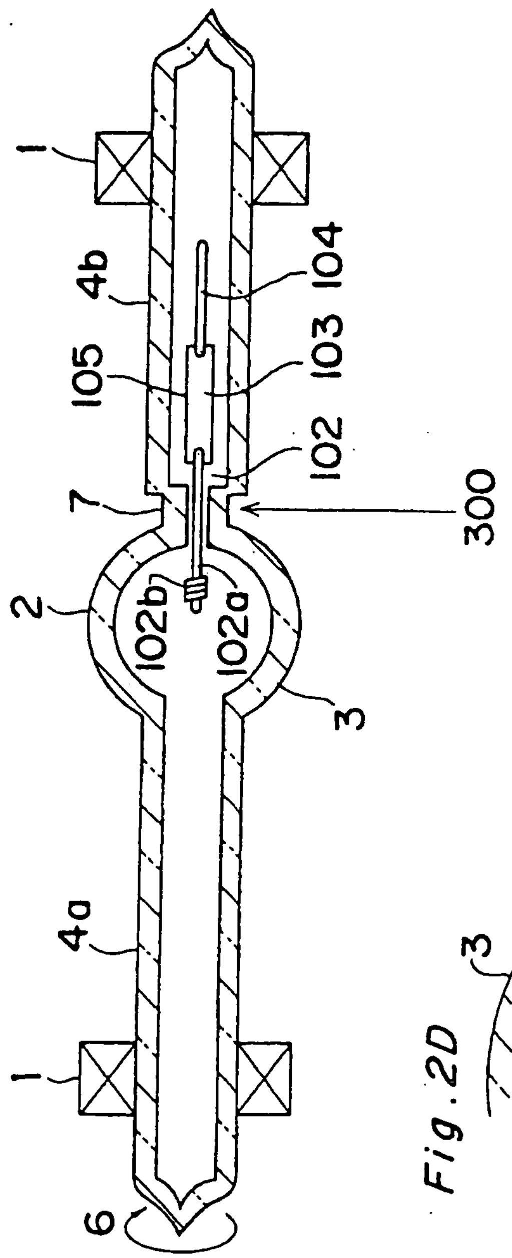
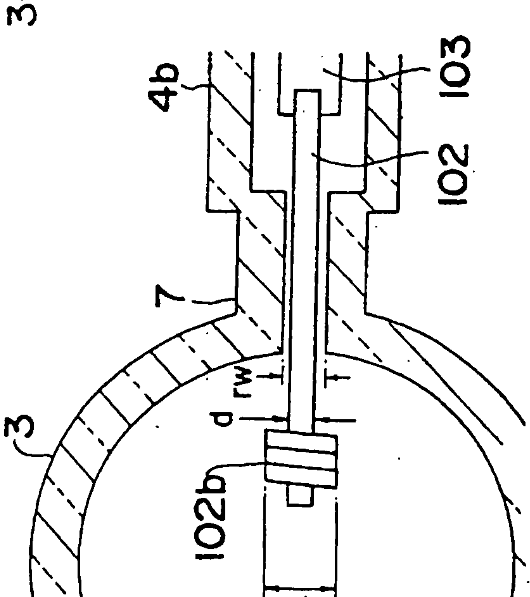

1
4b
105
104
103
102
7
300
2
102b
102a
3
4a
1
6

Fig. 2D


4b
103
102
7
3
d
rw
102b
L

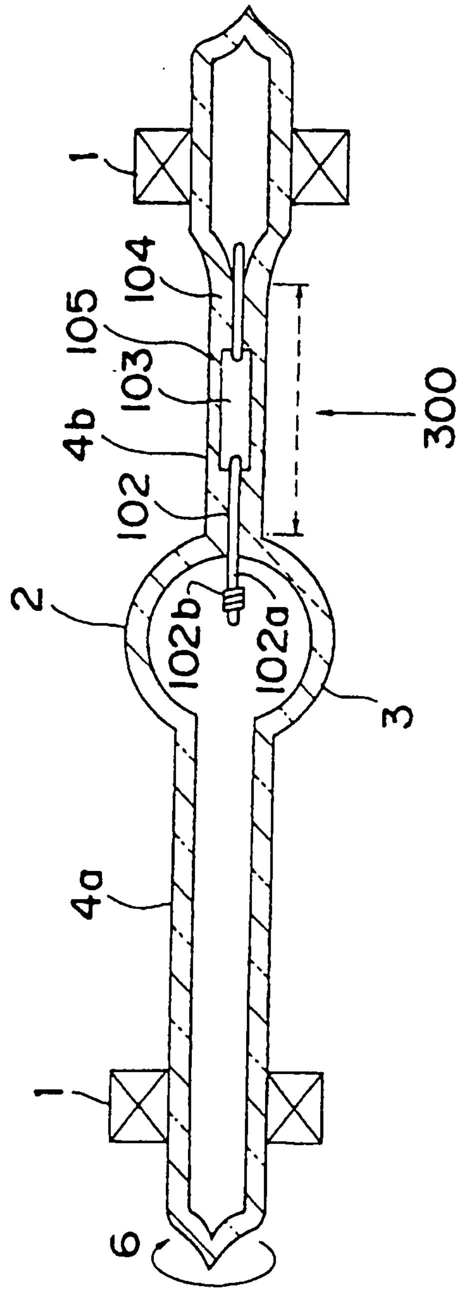


Fig. 2E

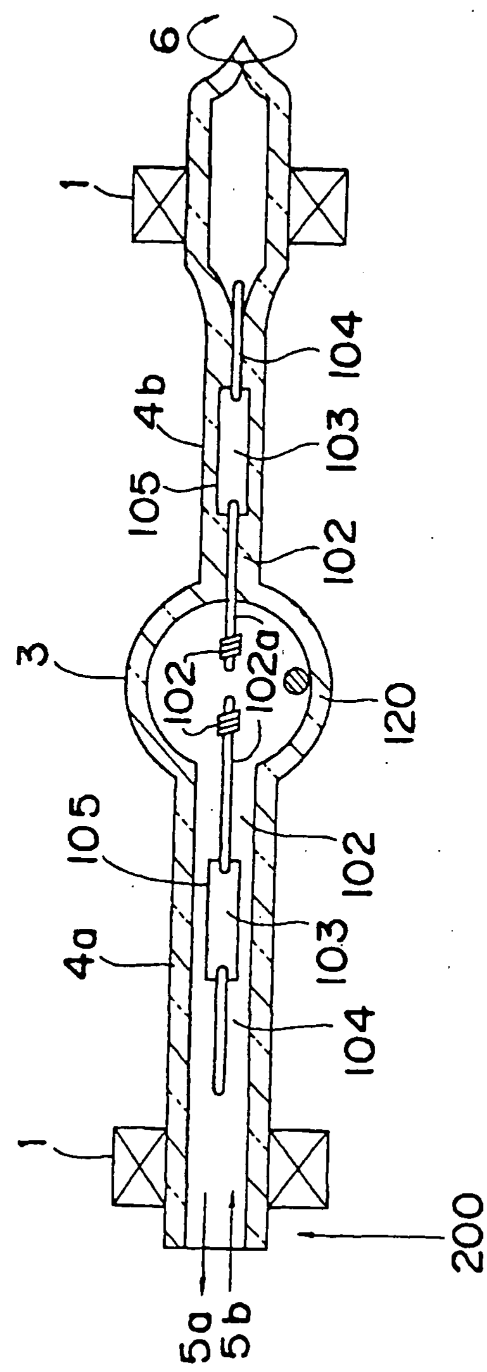


Fig. 2F

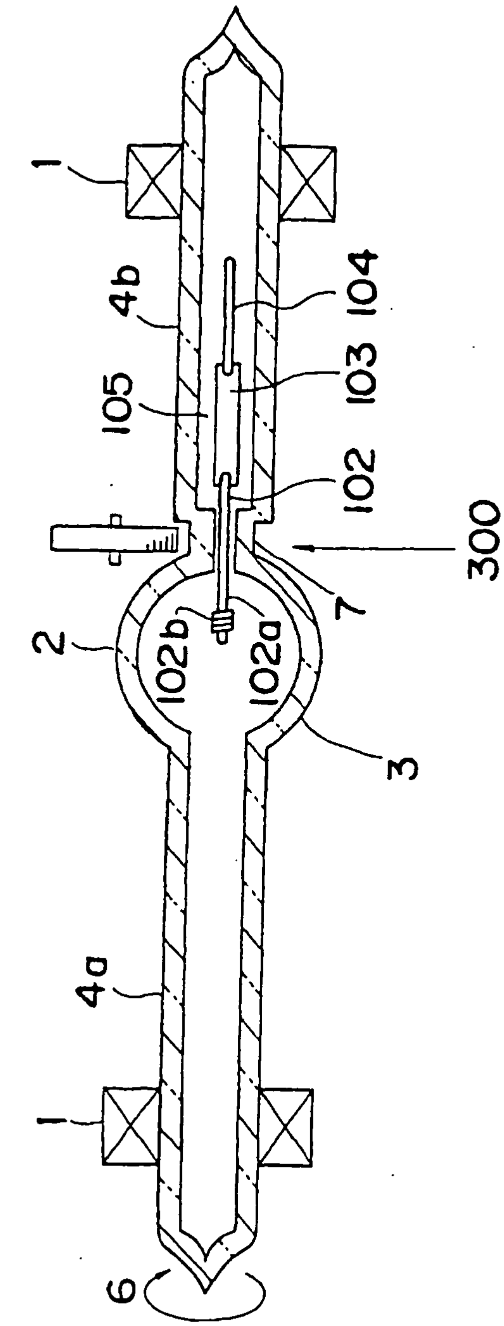


Fig. 3

Fig. 4

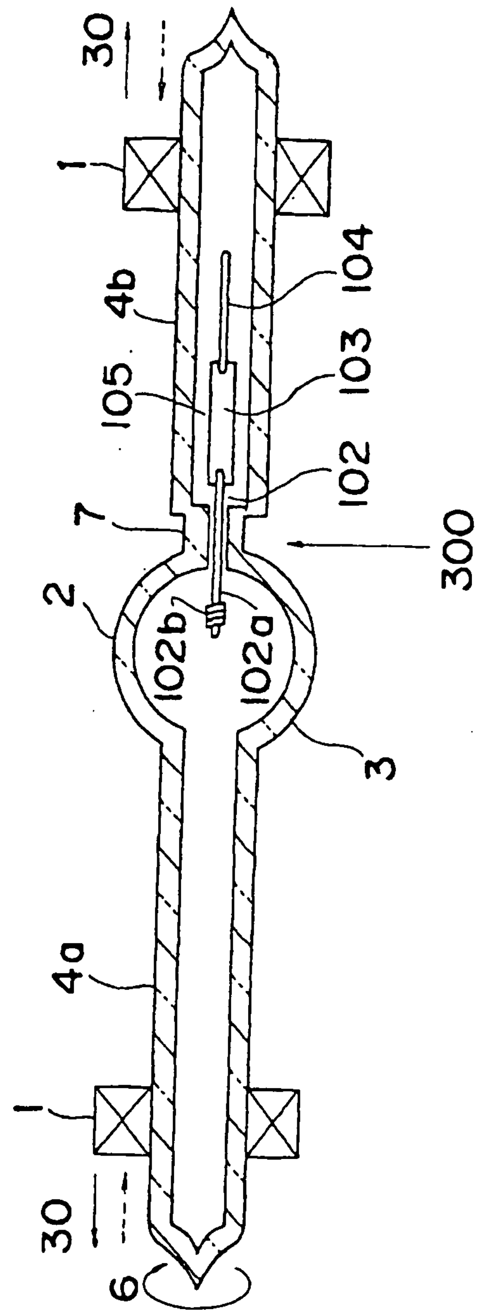


Fig. 5

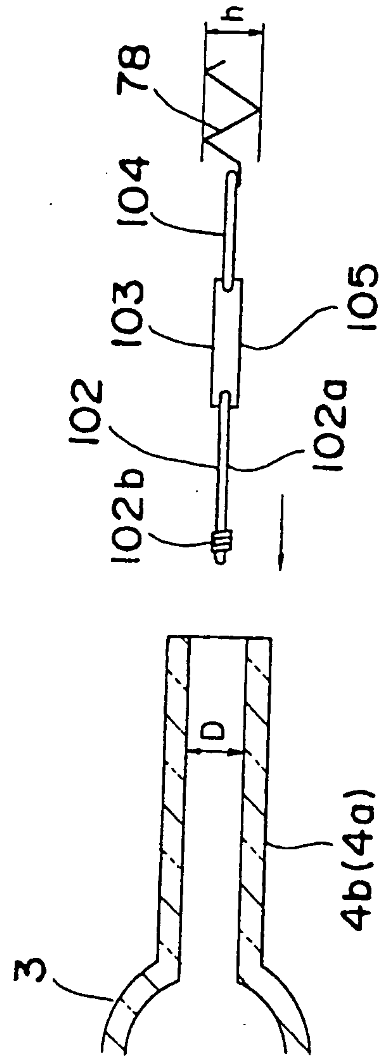


Fig.6A

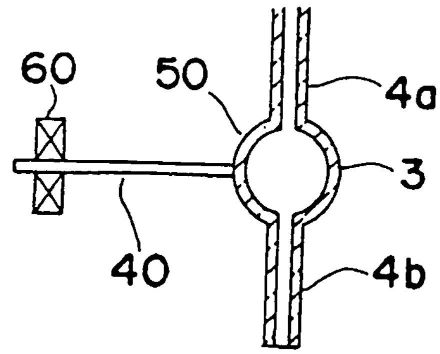


Fig.6B

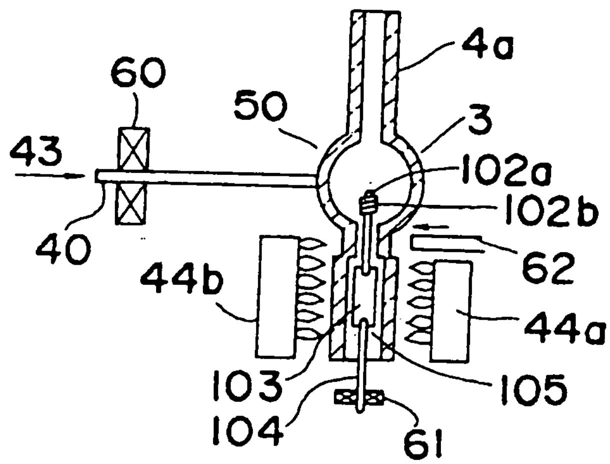


Fig.6C

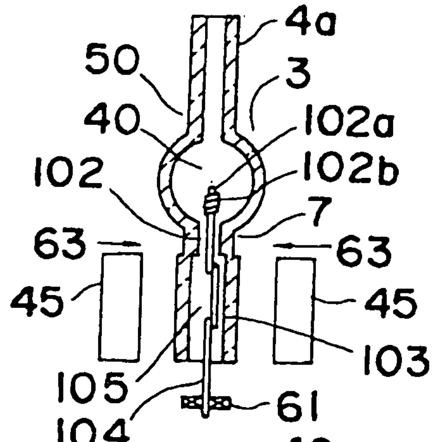
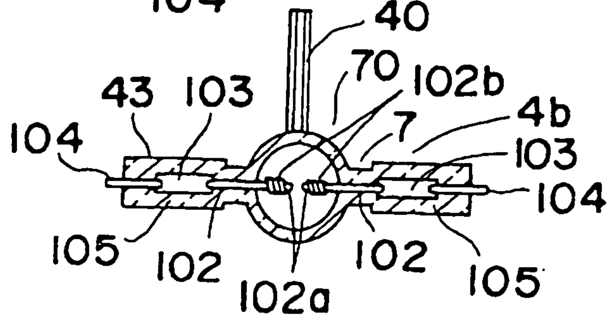


Fig.6D



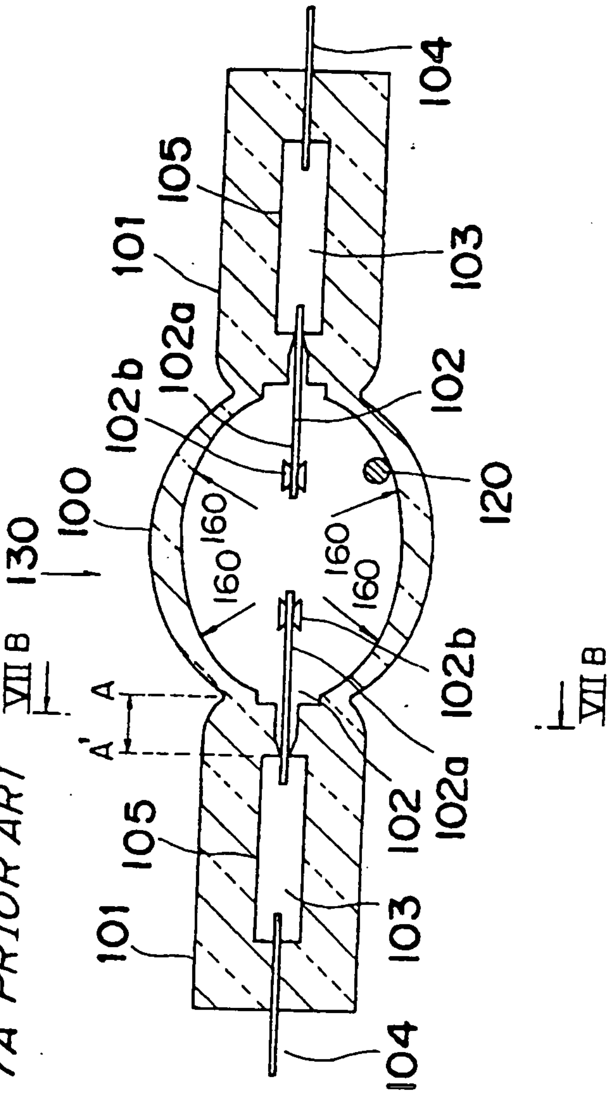


Fig. 7A PRIOR ART

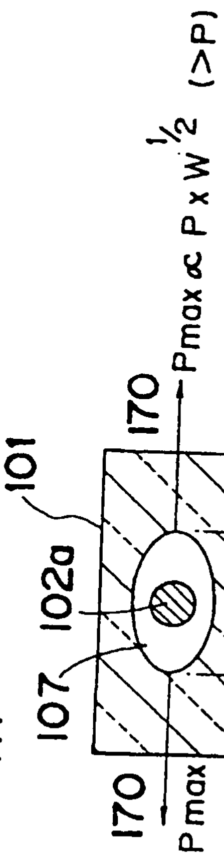


Fig.7B PRIOR ART

Fig. 8A
PRIOR ART

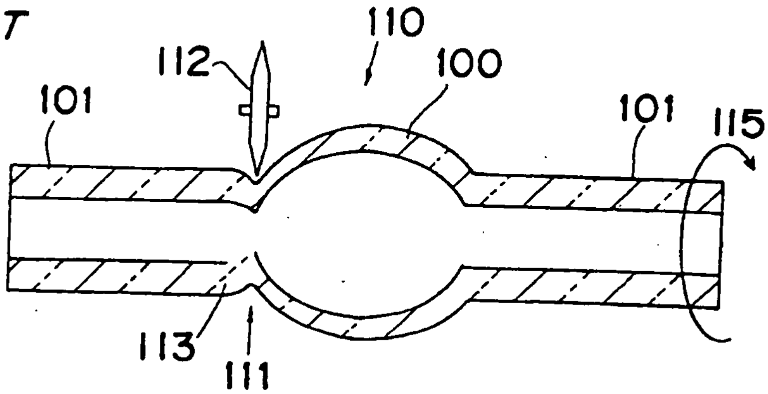


Fig. 8B
PRIOR ART

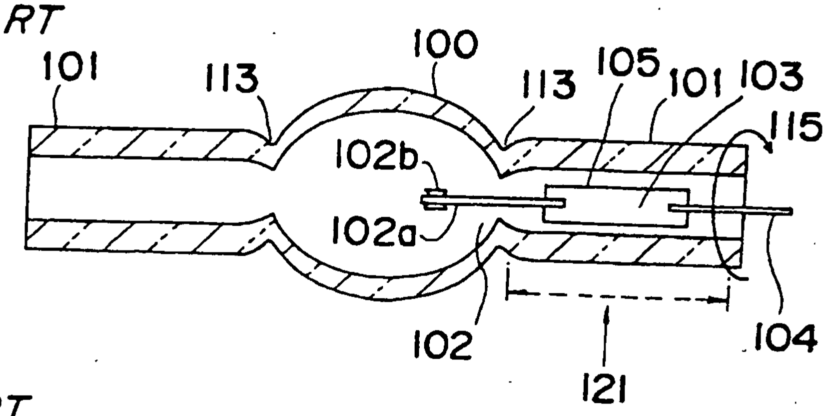


Fig. 8C
PRIOR ART

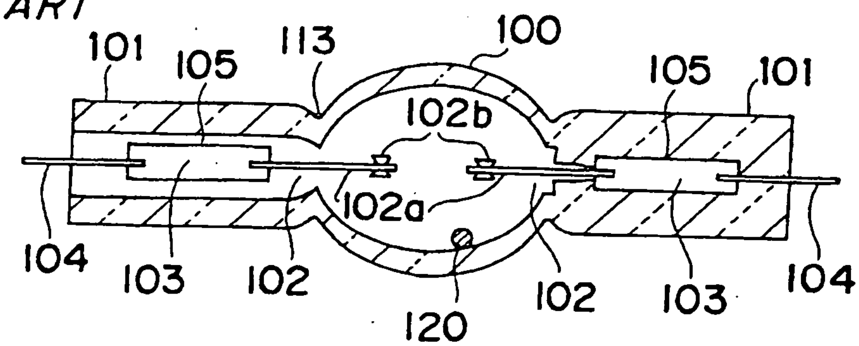


Fig. 8D
PRIOR ART

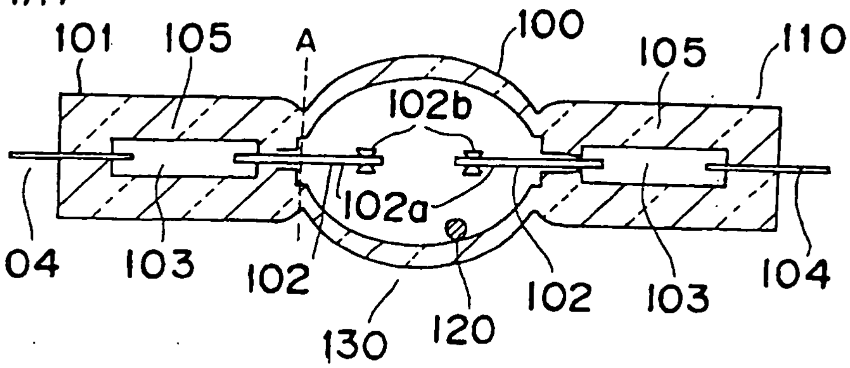
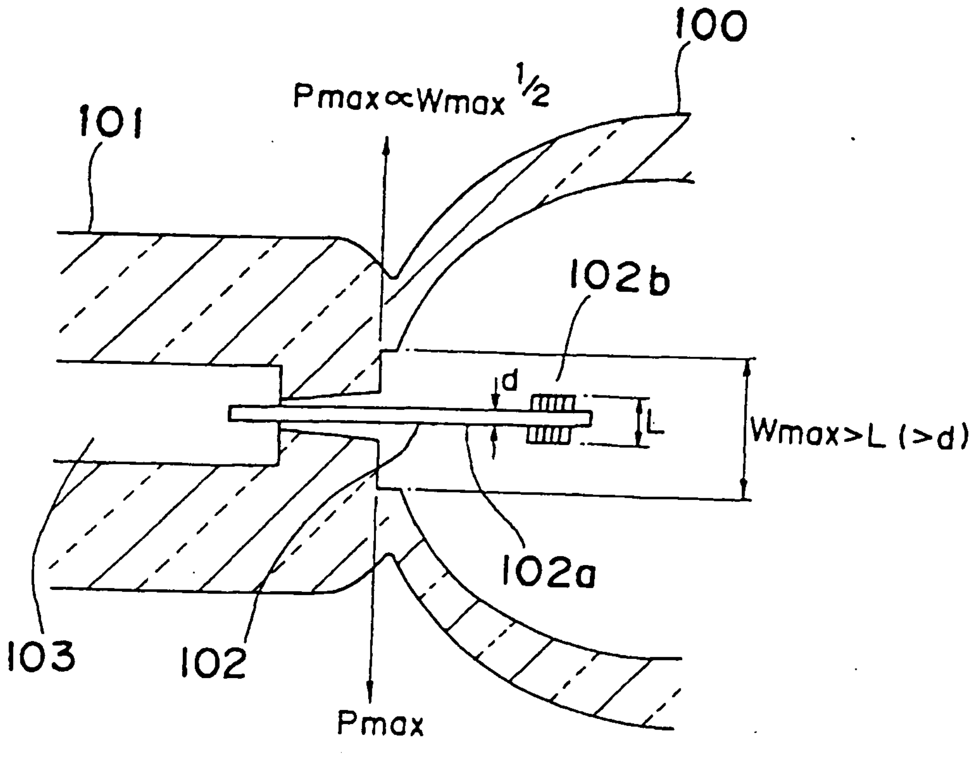


Fig. 9 PRIOR ART



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 10 4436

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	DATABASE WPI Section EI, Week 9550 Derwent Publications Ltd., London, GB; Class X26, AN 95-387077 XP002067752 * abstract * -& PATENT ABSTRACTS OF JAPAN vol. 96, no. 2, 29 February 1996 & JP 07 262967 A (MATSUSHITA ELECTRON. CORP.) * abstract *	1,2,7,9,12,14	H01J9/32 H01J61/36 H01J61/30 H01J61/82 H01J61/84
Y		5,6,10,11	
X	FR 2 100 245 A (GEN ELECTRIC) 17 March 1972	1,3,14	
Y	* page 1, line 7 - line 12 * * page 2, line 31 - page 3, line 13 * * page 4, line 31 - page 5, line 10 * * page 5, line 28 - line 41; figures *	2,5,6,9	
X	US 2 244 960 A (NELSON) 10 June 1941	1,14	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Y		2,5,6,9-11	H01J
A	* page 1, left-hand column, line 4 * * page 1, left-hand column, line 11 * * page 1, right-hand column, line 1 - line 18 * * page 2, right-hand column *	3	
X	PATENT ABSTRACTS OF JAPAN vol. 008, no. 161 (E-257), 26 July 1984 & JP 59 060941 A (IWASAKI DENKI KK), 7 April 1984,	13	
A	* abstract *	1,2,5,6	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 June 1998	Martín Vicente, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 10 4436

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A	PATENT ABSTRACTS OF JAPAN vol. 008, no. 190 (E-263), 31 August 1984 & JP 59 079955 A (IWASAKI DENKI KK), 9 May 1984, * abstract *	13 1,2,5,6	
Y	US 5 505 648 A (NAGASAWA MASAKAZU ET AL) 9 April 1996 * abstract * * column 4, line 15 - line 24 *	1,2,5,6	
Y	US 4 086 075 A (EKKELBOOM TJEPKE HENDRIK ET AL) 25 April 1978 * abstract; figures * * column 1, line 13 - line 20 *	1,2,5,10	
Y	PATENT ABSTRACTS OF JAPAN vol. 007, no. 186 (E-193), 16 August 1983 -& JP 58 089756 A (TOKYO SHIBAURA DENKI KK), 28 May 1983, * abstract; figures 1-4 *	1,2,8,11	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
P,X	EP 0 818 804 A (KOITO MFG CO LTD) 14 January 1998 * column 3, line 17 - line 29 * * column 3, line 44 - column 4, line 4 *	14-16	
P,X P,Y	DE 197 10 204 A (KOITO MFG CO LTD) 30 October 1997 * page 2, line 26 - line 36; figures 1,2,5,6 *	1-3,5-7,9,13 8,10,11	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 June 1998	Martín Vicente, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)